J. King Saud Univ., Vol. 5, *Science* (1), pp. 39–46 (A.H. 1413/1993)

Heavy Metals Analysis of Water and Soils from Saudi Arabia

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(Received 7 July 1991; accepted for publication 2 June 1992)

Abstract. Soils and water samples were collected from different places in Saudi Arabia (Abha, Arar, Dammam, Gizan, Hail, Madinah, Riyadh, Tabouk, Taif and Yanbu) and analyzed chemically for heavy metal concentrations. Soil samples from these places differed greatly in the concentrations of aluminium, bromide, cadmium, cobalt, copper, iron, lead and zinc, while water samples differed only slightly.

Introduction

Pollution of soils and water by heavy metals occurs due to industrial wastes, application of fertilizer, corrosion of sheeting, wires, pipes and burning of coal and wood [1,2,3,4]. The basic natural processes contributing trace elements to water are chemical and physical weathering of rocks and soil leaching. Biological and microbiological factors also contribute. Most trace elements, especially heavy metals, do not exist in soluble forms for a long time in water. They are present mainly as suspended colloids or are fixed by organic substances [5]. Trace elements originating from various sources in Saudi Arabia may finally reach the surface soil, and their further fate depends on soil chemistry and physical factors. Although the chemistry of soil and water contamination recently has been the subject of different studies, our knowledge of the behavior of pollution by trace elements in Saudi Arabia is limited [6].

The present study aimed at establishing the trace elements concentrations of soil and water from different places in Saudi Arabia. The study is important as pollution due to acid rain and burning Kuwaiti oil wells after the Gulf War, threatened to increase the heavy metal concentrations in soil and water resources of Saudi Arabia.

Materials and Methods

A. Water analysis

The methods for sampling water were similar to those described by Saudi Arabian Standard Organization [7, p. 407]. Samples of water from different places (Fig. 1) were collected in 100 ml polyethylene plastic bottles with screw caps. The procedures for mineral analysis of water were the same as described for soil analysis below. Six replicates of each water sample were taken for mineral analysis. The samples were kept in the refrigerator at 10° C until analyzed.

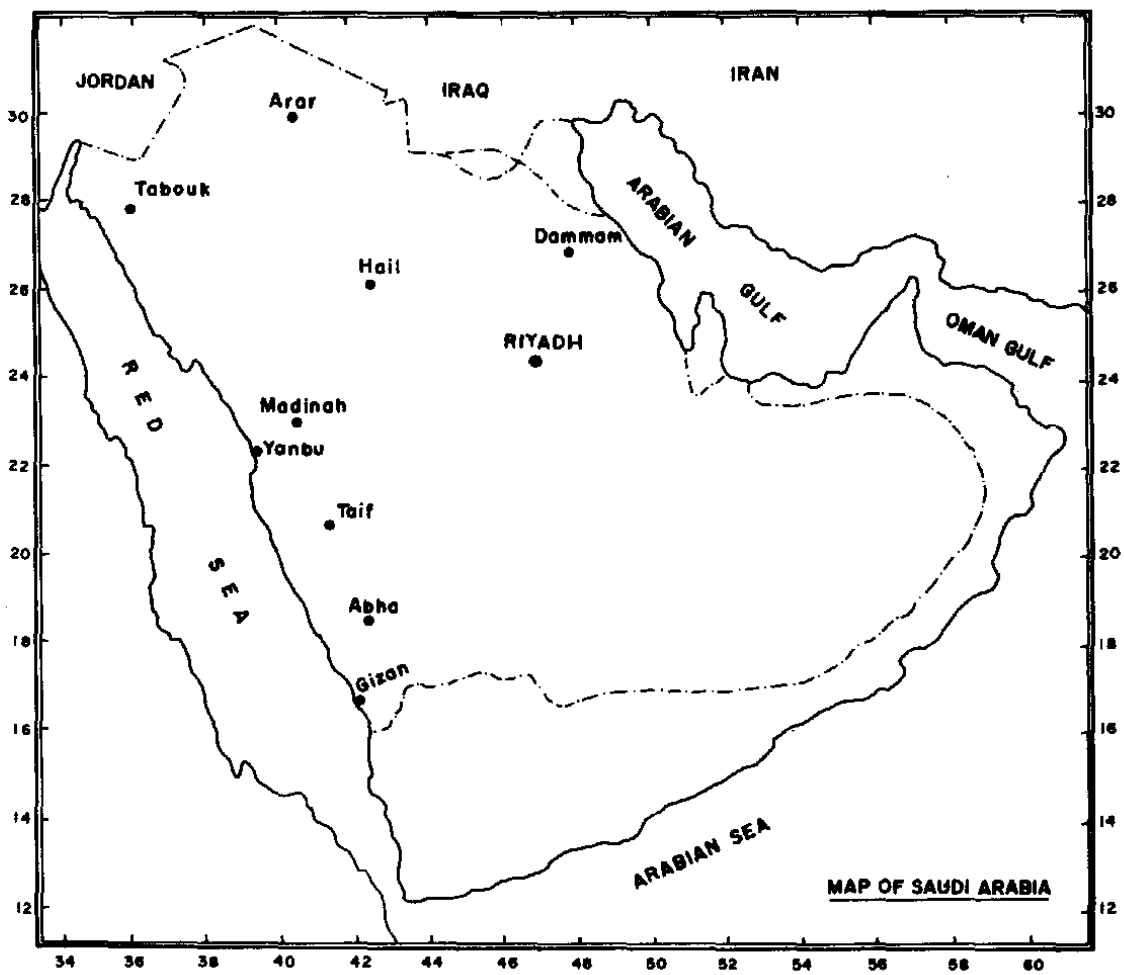

Fig. 1. Map showing the sites of soil and water samples collection

B. Soil analysis

Soil samples were collected from exposed soil surfaces. In each case the soil (1-10 cm depth) was put into a plastic bag using a stainless steel spoon. In the laboratory all samples were passed through a 2.0 mm sieve and were digested in concentrated nitric acid for metal analysis. The procedure was as follows: 0.5 g of air dried soil was placed in a 100 ml beaker with 20 ml concentrated nitric acid, covered with a watch-glass and heated at 100° C for 20 min. [6]. This extract was made up to 50 ml with deionised water and analysed using an atomic absorption spectrophotometer for determining Al, Br, Cd, Co, Cu, Fe, Pb and Zn.

Results

The total organic matter for the tested soil ranged between 0.05% and 1.03%, while the clay contents varied between 10% in Yanbu soil and 58% in the soil from Hail, (Table 1). The pH of tested soils from different places did not vary much and was almost neutral (pH range 7.03 – 7.55).

The results of water analysis are summarized in Table 2. The water from the ten places differed slightly in the concentrations of a particular metal. Water from Dammam and Yanbu contained the highest amounts of each metal. Soil samples differed greatly. Dammam and Yanbu soil were richer in metals than the other soils (Table 3). The optimum and maximum concentration of metals in unbottled drinking water, analysed by Saudi Arabian Standard Organization and International Standard is given in Table 4.

In general, with some exceptions, the Eastern region (Dammam) and Western region (Yanbu) soils had higher concentrations of heavy metals as compared to the Central (Riyadh and Hail) and Northern (Arar and Tabouk) region while the lowest

Table 1. Percentage of organic matter content, clay content and pH values of the soils tested

Source	Organic matter %	Clay content %	pH
Abha	1.01	50	7.05
Arar	0.45	47	7.15
Dammam	0.05	25	7.3
Gizan	0.32	43	7.45
Hail	1.03	58	7.5
Madinah	0.8	46	7.55
Riyadh	0.63	30	7.2
Tabuk	0.76	40	7.4
Taif	1.02	55	7.03
Yanbu	0.09	10	7.6

Table 2. Element concentrations of water samples (mg L^{-1}) from different places in Saudi Arabia (n =6, ± standard deviation).

Source	Elements							
	Al	Br	Cd	Co	Cu	Fe	Pb	Zn
Abha	0.03±0.02	0.11±0.03	0.005±0.001	0.01±0.001	0.05±0.01	0.04±0.01	0.005±0.001	0.11±0.01
Arar	0.07±0.01	0.15±0.01	0.007±0.002	0.02±0.001	0.08±0.03	0.01±0.01	0.003±0.001	0.15±0.01
Dammam	0.09±0.02	0.32±0.01	0.01±0.001	0.03±0.002	0.53±0.01	0.63±0.01	0.004±0.001	0.46±0.01
Gizan	0.05±0.01	0.28±0.01	0.003±0.001	0.03±0.003	0.18±0.01	0.06±0.02	0.002±0.001	0.2±0.02
Hail	0.08±0.03	0.16±0.02	0.002±0.001	0.02±0.001	0.09±0.01	0.31±0.01	0.001±0.001	0.13±0.02
Madinah	0.04±0.02	0.13±0.01	0.005±0.002	0.006±0.001	0.31±0.02	0.23±0.05	0.002±0.001	0.11±0.02
Riyadh	0.06±0.01	0.20±0.01	0.003±0.001	0.005±0.001	0.04±0.01	0.38±0.04	0.003±0.001	0.22±0.01
Tabouk	0.03±0.01	0.17±0.03	0.004±0.001	0.03±0.001	0.11±0.01	0.21±0.01	0.002±0.001	0.31±0.01
Taif	0.05±0.02	0.11±0.03	0.003±0.001	0.1±0.001	0.01±0.02	0.36±0.01	0.003±0.001	0.33±0.01
Yanbu	0.08±0.03	0.38±0.01	0.01±0.001	0.05±0.003	0.61±0.01	0.53±0.01	0.001±0.001	0.46±0.01

Table 3. Element concentrations of soil samples (ug g^{-1}) from different places in Saudi Arabia (n = 6, ± standard deviation).

Source	Elements							
	Al	Br	Cd	Co	Cu	Fe	Pb	Zn
Abha	1.00±1.1	1.61±0.61	1.8±0.2	6.2±2.1	11.1±1.1	25.1±1.1	10.1±1.1	6.3±2.1
Arar	81±1.0	0.8 ±0.0	1.1±0.8	9.3±2.3	13.1±2.2	20.1±1.9	9.19±1.9	7.9±1.8
Dammam	310±3.1	3.1 ±0.9	2.6±0.2	20.1±1.9	29±2.1	30.6±2.1	31.1±1.9	10.7±2.1
Gizan	101±0.9	1.3 ±0.8	1.3 ±0.3	11.1 ±1.9	12.3±1.3	28.2±1.3	11.81±1.2	6.3±1.1
Hail	93±1.1	0.1 ±0.1	1.1±0.8	13.3±2.9	5.8±0.6	19.1±2.1	8.8±1.8	6.3±1.9
Madinah	86±2.1	0.2 ±0.0	0.7±0.1	6.0±1.0	10.1±1.7	23.1±1.7	10.6±1.6	6.7±1.9
Riyadh	80±1.8	0.2 ±0.0	0.9±0.1	8.2±2.1	7.1±1.3	28.1±1.9	8.8±1.8	4.2±1.7
Tabouk	110±1.6	0.1 ±0.0	1.1±0.1	10.1 ±1.1	11.1±1.1	30.1±1.1	6.7±1.7	5.8±1.2
Taif	120±1.8	0.3 ±0.0	0.8±0.2	12.1±1.1	8.1±0.9	31.1±3.1	13.1±1.9	8.2±1.9
Yanbu	270±2.3	4.2 ±1.1	2.3±0.2	25.1±2.5	31 ±1.1	43.1±3.1	26.1±1.9	13.3±2.8

Table 4. Limits of mineral concentration of unbottled drinking water (according to Saudi Arabian and International standards of drinking water).

Element	Optimum (mg L^{-1})	Maximum (mg L^{-1})
Aluminium (Al)	–	–
Bromide (Br)	–	–
Cadmium(Cd)	0.01	0.05
Cobalt (Co)	–	–
Copper (Cu)	0.05	1.5
Iron (Fe)	0.1	1.0
Lead (Pb)	0.05	0.1
Zinc (Zn)	5.0	15.0

concentrations of heavy metals were observed in the South-Western region (Abha, Jizan and Taif).

Discussion

The presence of A1 in trace amount in all water samples resembles the findings of Mengel and Kirkby [8]. The concentrations of Br, Cd, Co, Cu, Fe, Pb and Zn in the water were below the upper limits of Saudi Arabian Standard Organization [7] and International Standard [9]. The concentration of A1 recorded here was similar to earlier findings [10, 11]. The concentration of Br in the soil was lower than reported earlier [12, 13]. The high metal concentrations in the water might be due to pollution as a result of the Gulf War and burning of Kuwaiti oil wells.

Cadmium is most mobile in acidic soils within the range of pH 4.5 to 5.5, whereas in alkaline soil Cd is rather immobile [14]. Cadmium content of surface soils of different countries ranged from 0.2 to 400 ug g^{-1} (total contents) but are in most cases about 1 ug g^{-1} or below [15, 16]. In the present study cadmium content of different soils ranged from 0.8 to 2.6 ug g^{-1}.

The content of cobalt is high in ultramafic rocks (100 to 200 ug g^{-1}) when compared to its content in acid rock (1 to 15 ug g^{-1}) [5]. Factors contributing to Co deficiency for grazing animals are mainly associated with alkaline or calcareous soils, slightly leached soils and soils with high organic matter content [5]. In the present study Co content of different soils ranged from 6.2 to 25.1 ug g^{-1}, whereas Co content of surface soils of different countries ranges from 0.8 to 122 ug g^{-1} (total contents) [17, 18, 19]. The concentrations of Cu in the above soil resemble earlier findings [20, 21]. The concentration of Fe in the present study resembles the earlier findings from Saudi Arabia [6]. Lead in the top horizon of different soils from various countries

ranges from 3 to 189 ug g^{-1} [22, 23, 24]. In the present study Pb content of analysed soils ranged from 6.7 to 31.1 ug g^{-1}. Pb occurs mainly as Pb^{2+}, although its oxidation state, +4 is also known, and it forms several other minerals which are quite insoluble in natural waters [5]. The mean Zn content in surface soils of different countries ranges from 17 to 125 ug g^{-1}, as total contents [25, 26], but Zn content in the present study ranged from 4.2 to 13.3 ug g^{-1}.

Heavy metal concentrations observed in the soils here were within the range reported earlier for some Saudi Arabian soils [6]. The organic matter contents found here were similar to earlier reports from Saudi Arabia [27, 28]. This study is a first attempt and part of a more extensive investigation in which the heavy metal contents of soil and water in different environments in Saudi Arabia are being determined.

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تحليل العناصر المعدنية الثقيلة لماء وتربة المملكة العربية السعودية

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(استُلم في ٣٦ ذي القعدة ١٤١١هـ؛ قُبل للنشر في ١ ذي الحجة ١٤١٢هـ)

ملخص البحث. تم في هذه الدراسة جمع عينات من الماء والتربة لمناطق مختلفة من المملكة العربية السعودية وتم تحليلها لتقدير محتواها من العناصر المعدنية الثقيلة.

أظهرت نتائج التحليل المعدني للماء تشابهها في جميع المناطق التي تم دراستها بينما المحتوى المعدني للتربة في المناطق السابقة يختلف عن بعضها البعض.

هذه الدراسة تعتبر جزءًا من الدراسة الشاملة التي يقوم بها الباحث في الوقت الحاضر لتقدير المحتوى المعدني للعناصر الثقيلة في المملكة العربية السعودية.